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# Model Based Estimation Of Turmeric Yield Response To Saline Groundwater Irrigation

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***Abstract: This study was conducted in South India to assess the impact of irrigation water quality with respect to salinity on soil salinity and turmeric (curcuma longa) crop yield. The study was preceded with watershed mapping of groundwater salinity using water samples from 95 randomly selected farmer owned tube wells. Twelve sites with varying groundwater salinity levels were selected for the detailed study. STICS crop model calibrated for the local conditions was used for prediction of potential turmeric yields under no nitrogen and salinity stress conditions. Soil and irrigation water chemistry was assessed through laboratory sample analysis using standard methods. Significant ($p \leq 0.05$) interactions were observed between irrigation water and soil salinity and between relative yield and soil salinity. Predicted yield, 7.5 (±0.474) t/ha, across plots was in agreement with expected yield, 7.2 t/ha, according to local data underscoring the model performance. The estimated yield gaps ranged between 2.1 t/ha where salinity level was lowest at ECe 0.84 dS/m to 5.7t/ha where soil salinity was Ece 2.1 dS/m. Our results indicate negative impact of irrigation related salinity on turmeric productivity in Berambadi watershed.***

***Keywords: Groundwater, modeling, salinity, turmeric yield.***

## I. INTRODUCTION

World agricultural productions in many areas are below the expected potentials with a maximum recorded relative yield under irrigation at 71% [1]. This highlights the need to identify yield gaps, why they exist and their extent, [1]. In so doing, predictions can be made of how much gain can be achieved by removal of such constraints. Evaluation of instability in productivity of turmeric in some South Indian states was carried out by [2], who concluded that yield instability dominated the causes of instability in production. They came to that conclusion after analysing time series data for the period 1979-80 to 1998-99 on productivity in the major turmeric growing states. They examined instability in area, production and productivity of the crop. The soil chemical properties in the Erode turmeric growing district of Tamil Nadu were analysed by [3] and they reported that all sampled sites were free from salinity and had pH values above neutral.

Land suitability as one cause of variation in yield was investigated by [4] and they noted that such analysis could only give information on productivity potential. They also made mention that available climate and soil data was inadequate to understand yield. This is quite plausible given that soil chemical factors like pH, salinity, and nutrient availability determine vegetation distribution, [5] and in turn crop yield, [6]. Apart from using land suitability, yield potentials (Yp) can be estimated using crop simulation models based on prevailing management, genetic features of the crop, weather and water supply [7].

This study tried to quantify the impact of irrigation water salinity on turmeric yield using simulated potential yield and observed yields. Turmeric crop (*curcuma longa)* was selected because [8] observed that turmeric was sensitive to saline soil and saline water irrigation. The crop is believed to be native to south East Asia [9] grown mainly for its colored rhizomes. India, at 78% production level, is the leading producer and also consumer of turmeric, [10].

A number of research studies relating irrigation water salinity to crop yields can be retrieved in literature: Semi-dwarf bread wheat [11]; broad bean [12]; maize and sunflower [13]; sorghum [14] and Chile pepper [15]. They all conclude that salinity significantly reduces yield. The extent depends on the level of salinity, climatic conditions, soil type and the tolerance of the crop to salt levels. No such study was found in literature on Turmeric crop and so the study was aimed at assessing the effect of groundwater quality with respect to salinity on crop yield testing with turmeric crop.

## II. METHODOLOGY

### A. SITE LOCATION

The study was done at Berambadi watershed located in the southern India state of Karnataka Fig.1. The area experiences mean monthly air temperature ranging between 18.0$^0$C - 30$^0$C minimum and maximum respectively. Annual precipitation is less than 900mm and it was less than 600mm during the study period, with relative humidity below 20%. The soil was predominantly sandy loam up to 30cm depth studied.

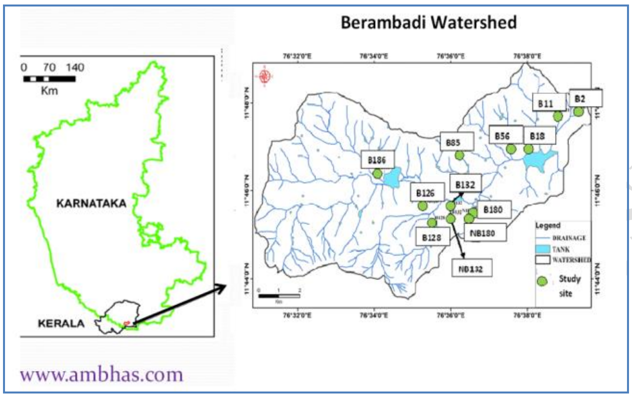


*Figure 1: Site map with Berambadi watershed presenting study sites*

### B. WATER SAMPLING AND ANALYSIS

*Water samples were collected from 95 tube wells* from pumped water into 125 ml polyethylene bottles. The bottles were washed with sample water first before filling them with water for laboratory analysis. Samples were kept under refrigerated condition and were brought to room temperature before the analyses. They were filtered through Millipore 0.45 µm 47 mm hydrophilic PVDF filter paper cat no. HVLP04700.

Samples were analyzed for EC, pH, alkalinity and major cations and anion using standard methods as described under soil analysis.

### C. FIELD DATA COLLECTION

The farmers were grouped in three clusters using the water quality with respect to salinity; < 1dS/m, 1<water quality<1.5, and above 1.5 dS/m. In each category 4 farmers using furrow irrigation were selected and acted as replicates. A total of 12 sites were therefore selected for the study. A research plot of 25 m$^2$ was designated on each selected farmer's field on which the investigations were carried on. Planting was done on 17$^{th}$ April 2012 at a planting density of 9 plants /M$^2$ and harvesting was done on 12$^{th}$ December 2012 after 8 months. Local data indicated that the varieties grown were Roma and Suroma with yield potentials of 7.2 t/ha dry weight. Farmer's management practices were monitored and there was indication that they were well informed on planting dates, field management in terms of fertilizer application and had access to best suitable varieties. Surface (10 cm) and profile (>10 cm) soil moisture readings were recorded weekly using TDR moisture probes installed on the fields. Plant number of leaves, LAI, biomass at harvest and final yield of three plants were recorded in each research plot.

### D. SOIL SAMPLING AND ANALYSIS

Surface (30 cm) composite soil samples were collected from each research plot at start of season and at midseason following the procedure described in IS: 2720.

The soil samples were air dried within 1 day of collection and sieved through a 2 mm sieve IS 2720. They were analyzed for EC, O.M, pH, CEC and exchangeable cations of magnesium, calcium, potassium and Sodium as well as anions of sulfates, chlorides and total alkalinity as calcium carbonate. Average parameter values were computed and used for the evaluation.

Electrical Conductivity (EC) was estimated using the method IS: 2720 (Part 21) -1977, the value obtained was converted to ECe through multiplication by a factor of 4.9 for sandy loams and 3.9 for the finer soils. Cation levels were determined using Inductively Coupled Plasma (ICP), pH was determined electrometrically using the method IS: 2720 (Part 26) -1987, CEC was determined as the sum of major cations. Chlorides were determined using the Argenometric -Mohr method instrument model (877 Titrino plus 05202 5.877.0020) auto titrimeter. Alkalinity was volumetrically assessed according to IS: 2720 (Part 23) -1976 method, (Reaffirmed 1987). For sulphate analysis, the turbimetric method was used and readings were recorded using –UV spectrophotometer. Organic matter content was determined by colorimetric method and recorded using a single beam spectrophotometer at λ 610 nm. Soil texture was determined by combination of the wet sieve method for course particles and Laser beam particle analyser method for the fines.

### E. POTENTIAL YIELD ESTIMATION

Prediction of potential turmeric yield under the given site specific soil characteristics and common climatic data was done using *STICS* crop soil model. An overview of the model was documented by [16]. The model was earlier calibrated and validated under local conditions using turmeric as presented in (Fig.2) and also detailed in [17]. Relative yield was calculated as a ratio of observed yield to simulated yield.

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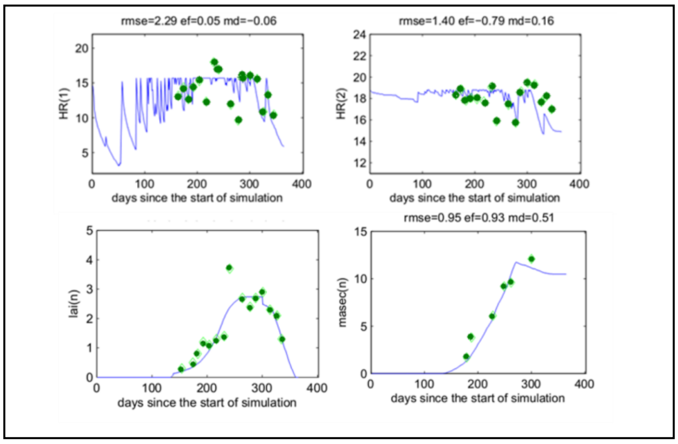


*Figure 2: Model output data on soil water in; upper layer (HR1) and lower layers (HR2) Leaf Area Index (LAI) and final yield (masec), validated against observed field data*

### F. IRRIGATION WATER SALINITY IMPACT ASSESSMENT

The impact due to irrigation water salinity on yield was evaluated following the chart presented in Figure 3.

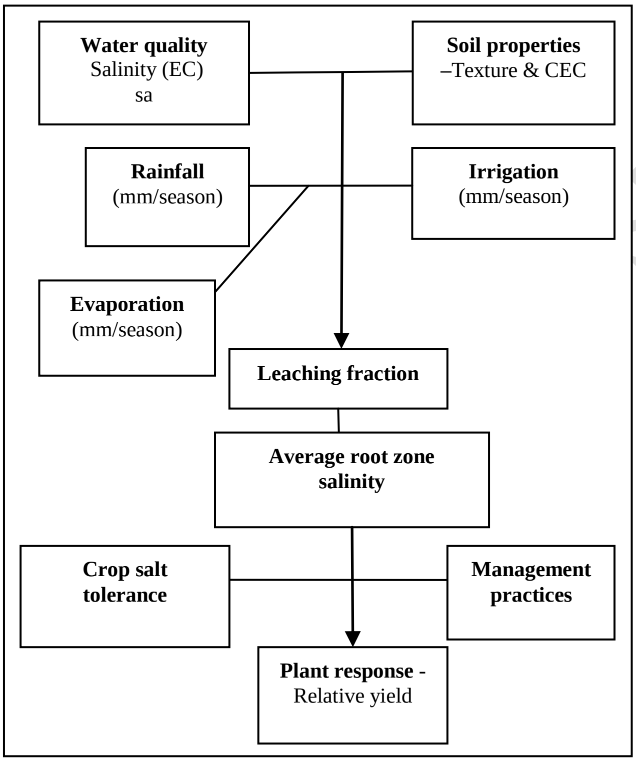


*Figure 3: Irrigation water salinity impact evaluation flow chart modified after, ANZECC and ARMCANZ (2000)*

The irrigation water was moderately saline judging by [18] and [19] irrigation water guidelines. Groundwater salinity levels were generally higher in May compared to September and increased again in December. Soil salinity was low at some sites and slightly saline at others (0.7- 2.1) dS/m but was sufficient to cause yield reduction in turmeric crop.

The irrigation water-soil salinity response curves were similar to those reported in [18] and [20]. The regression value for the response of soil salinity to irrigation water salinity was however small ($R^2$=0.37$^{**}$), which may imply that many factors other than irrigation salinity explain soil salinity variations. But, given that the data analyzed are for different sites, presenting different soil conditions, different cropping cycles and different number of years of irrigation application all of which have potential to influence the soil salinisation (Ref. Fig 2), the interaction was significant.

Sulfate levels were very low (0.4-1.35) meq/L in irrigation water and undetectable in the soil at most sites (*Acidic NaOAC*). Alkalinity, in the irrigation water was moderate at some sites and high at others, (3.2-7.2) meq/L while that in the soil ranged between 6.5 and 24.5 % as $CaCO_3$. Sodium and magnesium levels in the irrigation water and on the soil exchange sites showed some correlation at $R^2$=0.57$^{**}$ and $R^2$=0.53$^{**}$ respectively. Both irrigation water and the irrigated soils generally indicated alkaline reaction.

## III. EFFECT OF SALINITY ON TURMERIC

Salinity affected yield through reduction in number of rhizomes per plant. The average number of rhizomes per plant was not counted but it can clearly be seen from Figure 4 that plants at some sites had significantly fewer number of rhizomes.


*Figure 4: Rhizomes of plants harvested from sites with varying soil salinity levels (1 stool per site)*

There was strong negative correlation ($R^2$=0.69$^{**}$) between relative yield and soil salinity (Fig. 5). This result clearly indicated that the prevailing soil salinity levels negatively affected turmeric production through yield reduction. Assuming yield at ECe 0.84 dS/m as yield for non – saline condition, a 44% yield reduction due to salinity occurred at ECe 2.1 dS/m. Results from other similar studies on different crops done by [21] indicated 25% yield reduction at ECe values: 1.5 dS/m for beans; 1.9 dS/m for cabbage; 1.8 dS/m for onion and 1.2 dS/m for straw-berry all categorized as sensitive crops.

The regression values to soil salinity were $R^2$=0.57$^{**}$ and $R^2$= 0.75$^{**}$ for observed and yield gap respectively. Observed yield data regression coefficient was the lowest which would give liberal impression of salinity impact without due regard to the yield potential of each site. The simulated yield data, assumed as potential yield, showed that fine textured soils had slightly higher yield potentials and these sites from soil analysis were generally more saline.

The yield gap regression value indicated a high impact of salinity on turmeric but at any one site, many factors exist that naturally inhibit attainment of full yield potentials. Relative yield correlation coefficient at $R^2=0.69^{**}$ was close to the mean of the other two $R^2=0.66^{**}$ and is seemingly the most appropriate parameter for salinity evaluation.

From the same Figure, a monotonically increasing yield gap between expected yield and observed yield was evident. The widest gap was however observed at the site with salinity level ECe 1.67 dS/m. The site had calcareous soils at 24.5 % as $CaCO_3$. In their detailed description of adaptation of plants to adverse conditions,[22] noted that iron deficiency was the most prominent crop plant nutritional disorder at alkalinity values above 20% as $CaCO_3$. It may be inferred that existence of another stress factor caused further depression of yield at that site.

The maximum percentage relative yield obtained from this data was 71% at ECe 0.84 dS/m which compared well with that reported in literature at (70-80 %).

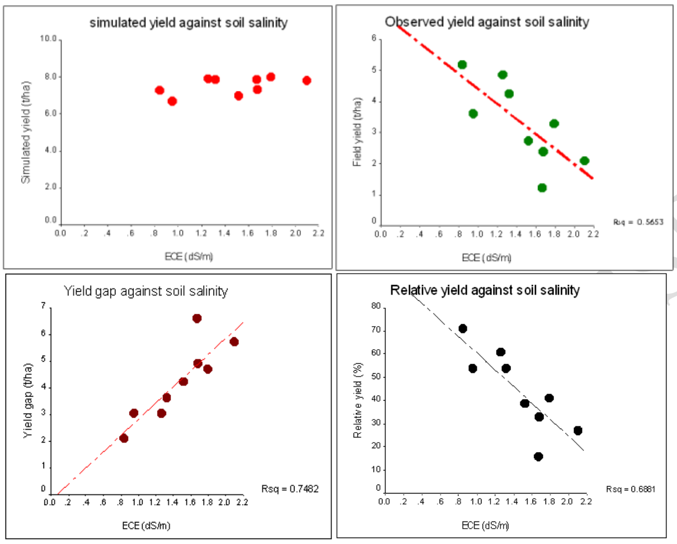


*Figure 5: Scatter plots of Simulated yield, observed yield, yield gap (t/ha) and percentage relative yield against soil salinity*

## IV. CONCLUSIONS

Modeling may be used to evaluate impact of water quality on crop performance. The productivity potential of each site should be put into consideration as use of a blanket potential yield may give misleading results.

Turmeric crop may not withstand saline irrigation water. Yield indicated negative response within the investigated soil salinity levels (0.8-2.1;dS/M) confirming that the crop is sensitive to salinity.

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